DEVELOPMENT OF COMPACT ANTENNA FOR RFID APPLICATION

ABDULKADIR MUKHTAR DIBLAWE

A project report submitted in partial
fulfilment of the requirement for the award of the
Degree of Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

JANUARY 2019

Sincerely dedicated to my beloved Mother and Father…

ACKNOWLEDGEMENT

Deep and humble gratitude to ALLAH Almighty for providing the opportunity and giving me the strength to complete this work.

I would like to express heartiest thanks to my supervisor Assoc. Prof. Dr. Noorsaliza Binti Abdullah whose encouragement, guidance and continuous support enabled me to carry out this research work.

Most importantly I would like to thank my parents who have always been there for me for their support financially and for their endless encouragement and prayers, not to forget my sisters, my brothers, other family members and friends in Somalia and Malaysia for supporting me spiritually throughout this work and my life in general.

Finally honorable thanks to all my colleagues, lecturers and everyone involved directly and indirectly towards completion of this work especially Mr.Abdul Rashid Omar Mumin, faculty of Electrical and Electronic Engineering and all UTHM stuff.

ABSTRACT

In recent years, microstrip antennas have met commercial requirements. The advent of wireless applications requires a compact antenna, easy to manufacture. The goal of the project is to develop a microstrip monopole antenna for RFID tag applications that reduce size. The purpose of this antenna is to operate at 2.4 GHz. Due to its low-profile, a microstrip monopole antenna was chosen as a design model for the project.CST Microwave studio 2015 has been used to simulate the design of antennas for preliminary design purposes. This can be recognized as being unique to the advantages of the antenna. . The proposed antenna was etched on an FR4 substrate with an overall size of 40 mm × 17 mm × 1.6 mm. The successful implementation of the modified ground plane allows the miniaturization and provides excellent performance. The performance of an antenna shows agreement between both simulation and measurement results.

ABSTRAK

Tahun-tahun kebelakangan ini, mikrojalur antena telah memenuhi keperluan komersial. Penciptaan aplikasi wayarles memerlukan antena padat, mudah untuk mengilang. Tujuan projek ini adalah untuk memanfaatkan mikrojalur antena ekakutub bagi aplikasi penandaan RFID yang menggurangkan saiz. Tujuan antena ini adalah untuk beroperasi pada 2.4Ghz. Oleh kerana ia tidak menonjolkan diri, mikrojalur antena ekakutub telah dipilih sebagai modal rekabentuk untuk projek ini. CST Microwave studio 2015 telah digunakan untuk simulasi rekabentuk antena bagi persediaan awal proses reka bentuk. Ini boleh diperakui sebagai unik untuk memanfaatkan antena. Antena yang dicadangkan ini telah bergores pada substrat FR4 dengan saiz keseluruhan ialah 40 mm x 17 mm x 1.6mm. Kejayaan pelaksanaan oleh muka tanah terubah suai membolehkan pengecilan dan menyara kepada prestasi cemerlang. Prestasi antena ini menunjukkan persetujuan tentang kedua-dua simulasi dan keputusan ukuran.

CONTENTS

TITLE		**i**
DECLARATION		**ii**
DEDICATION		**iii**
ACKNOWLEDGEMENT		**iv**
ABSTRACT		**v**
ABSTRAK		**vi**
LIST OF TABLES		**x**
LIST OF FIGURES		**xi**
LIST OF SYMBOLS AND ABBREVIATIONS		**xiii**
CHAPTER 1	**INTRODUCTION**	**1**
1.1	Background Study	1
1.2	Problem Statement	2
1.3	Objectives	3
1.4	Scope of Study	3
1.5	Thesis outline	4
CHAPTER 2	**LITERATURE REVIEW**	**5**
2.1	Overview	5
2.2	Background of RFID	5
2.3	RFID tag	8
2.4	RFID Reader	10
2.5	Frequency range of RFID	11
2.6	RFID Applications	13

		2.6.1 Common types of RFID Antennas	14
		2.6.2 Previous study	15
CHAPTER 3		**METHODOLOGY**	**21**
	3.1	Introduction	21
	3.2	Procedures of Development of the Project	21
	3.3	Flow chart for antenna design	22
	3.4	Antenna Specification	23
	3.5	Material Specification	24
	3.6	Antenna Design Parameter	25
	3.7	Antenna Simulation	26
	3.8	Fabrication	27
	3.9	Measurement	27
CHAPTER 4		**RESULTS AND DISCUSSION**	**30**
	4.1	Introduction	30
	4.2	Simulation Result	30
		4.2.1 Return Loss	31
		4.2.2 Bandwidth	31
		4.2.3 Voltage Standing Wave Ratio (VSWR)	32
		4.2.4 Input Impedance	33
		4.2.5 Radiation Pattern	34
	4.3	Measurement Results	36
		4.3.1 Return Loss	36
		4.3.2 VSWR	36
		4.3.3 Input Impedance	37
	4.4	Comparison between Simulation and Measurement	38
		4.4.1 Return Loss	38
		4.4.2 VSWR	39
	4.5	Parametric Study	39

4.5.1 The simulated return loss with difference parameters slot of Length and Width (L and W) 40

4.5.2 The simulated return loss with difference parameters Length and Width of ground 41

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS 42

5.1 Introduction 42

5.2 Conclusion 42

5.3 Future Work and Recommendation 43

REFERENCES 44

LIST OF TABLES

2.1	Evaluation of Bar-code vs. RFID	6
2.2	RFID development completed the previous decades [11]	7
2.3	Categorization of RFID tags	9
2.4	Types of RFID readers	10
2.5	Frequencies of operation and characteristics performance [17]	13
2.6	Designated RFID uses in the public division	14
2.7	Summary of some previous papers	20
3.1	The specification of the antenna	24
3.2	The FR4 substrate specification	24
3.3	Value for parameter dimension	25
4.1	Radiation pattern for E-plane and H-plane	35
4.2	Return Loss difference between simulation and measurement	39

LIST OF FIGURES

2.1	Meander line antenna	15
2.2	Proposed slot microstrip antenna	16
2.3	Simulated S-Parameter at 2.4GHz	17
2.4	Design arrangement of the proposed fractal RFID tag antenna: (a) upper layer, (b) inter-CSRR layer, (c) bottom layer, (d) photograph of the assembled RFID tag, and (e) side view	18
2.5	Simulated return loss of the antenna	18
2.6	Multi-purpose switched multi-band antenna	19
3.1	Project flow chart.	22
3.2	Flow chart for antenna design	23
3.3	Dimension of the antenna	25
3.4	A screen-shot of CST Microwave Studio's main window	26
3.5	Fabricated antenna	27
3.6	Short, Matched and Open connectors	28
3.7	A straight line at 0dB of the S_{11} graph shown on VNA's screen	29
4.1	Simulated return loss for the proposed antenna	31
4.2	Simulated bandwidth	32
4.3	The simulated VSWR	33
4.4	Simulated input impedance	33
4.5	Simulated 3D far-field radiation pattern for directivity	34
4.6	Return Loss for measured antenna	36
4.7	VSWR for measured antenna	37
4.8	Smith Chart for measured antenna	37
4.9	Measured and simulated return loss for proposed antenna	38
4.10	Comparison measured and simulated of VSWR	39
4.11	The simulated return loss with difference L	40
4.12	The simulated return loss with difference W	41

4.13 The simulated return loss with difference ground 41

LIST OF SYMBOLS AND ABBREVIATIONS

c	-	Speed Of Light
D	-	Directivity
E	-	Efficiency
f	-	Operating Frequency
f_C	-	Centre Of Frequency
f_H	-	Upper Frequency
G	-	Gain
h	-	Substrate Thickness
L	-	Length
L_{eff}	-	Effective Length
R_{in}	-	Antenna Resistance
S_{11}	-	Return Loss Or Reflection Loss(Db)
X_{in}	-	Antenna Reactance
W	-	Width
Z_{in}	-	Input Impedance
Z_o	-	Characteristics Impedance
λ	-	Free Space Wavelength
ε_r	-	Dielectric Constant
ΔL	-	Extended Length Due To Fringing Field Effect
Γ	-	Reflection Coefficient
dB	-	Decibel
HPBW	-	Half Power Bandwidth
PCB	-	Printed Circuit Board
RL	-	Return Loss
SWR	-	Standing Wave Ratio
VSWR	-	Voltage Standing Wave Ration

CHAPTER 1

INTRODUCTION

1.1 Background Study

The extraordinary development in the field of RFID and its use and related applications has led to the need for smaller and more low-profile components that may be suitable for an application. Most RFID applications operate with a bandwidth of approximately 180 to 300 MHz for different frequencies, such as 120-150 kHz low frequency (LF), 13.56 MHz high frequency (HF), very high frequency (UHF) 433 MHz, 865 Frekans 868. MHz (Europe) 902-928 MHz (North America) UHF band, microwave band of 2450-5800 MHz and very broad band of 3.1 to 10 GHz [1].

Radio Frequency Identification (RFID) is a two-way contactless technology that uses electromagnetic induction and radiation. The generic RFID system includes a scanner unit, called a reader, and a series of remote transponders connected to objects that need to be identified by a tag [2]. It also includes software (middleware) and server processor (usually a PC) that communicates with remote tags. RFID is one of the promising technologies used as an alternative to addressing some of the problems associated with current identity technologies such as barcodes and optical systems. It sees RF waves to transmit data between the reader and the moving element to identify, classify and monitor. Currently, RFID technology advanced reading range, no sight of line, low cost, ability to use many things in one scan [3].

In recent years, RFID technology has been widely used in logistics transportation, traffic toll collection, employee participation records and animal husbandry management. Specifically, Internet of Things (IoT) development in industry and home applications brings stricter requirements for reliability, high-speed data rate, multi-band operation and cost-effectiveness to the reader antenna [4]. RFID tags are always routed in practical applications and the tag antennas are mainly linearly polarized (LP). Compared to LP waves, circularly polarized (CP) waves provide greater flexibility in the orientation angle between the reader and the tag. Therefore, the CP reading antenna is the primary solution for improving the communication security of the RFID system. In general, CP waves can be obtained by two or more LP orthogonal positions with equal amplitude and phase difference of 90° [5]. The recent development of wireless technologies for health application has led many scientists to industrial research. As the need for modern medical devices increase every day, the cost of medical care and hospitalization increases [6].

Radio Frequency Identification (RFID) is one of the fastest growing areas of automatic identification and collection of data in the medical industry. They are widely used to focus on patients, tracking and locating surgical instruments; supply chain observation, patient medication monitoring, neonatal identification, etc. In addition to the above, it is also useful for screening hospital staff, detecting blood bags, preventing detection of pharmaceutical products, access control to prevent theft of medical equipment, keeping a patient-friendly diet with laser markers and access to the status of medicines in biomedical applications [7]. RFID technology was actually developed around the Second World War. This bidirectional contactless data communication includes the transmitter and receiver components of the system. For example, a reader tags UHF RFID system that receives a signal from an RFID reader antenna from an open area in an RFID reader antenna [8-10]. Another application that uses this RFID technology is the successor of barcodes for retail supply chain, remote monitoring and medical surveillance.

1.2 Problem Statement

The RFID application has become essential in today's wireless technology. This application requires a radio frequency antenna, which is small enough to receive limited communication devices. Therefore, the aim of this project is to design and develop a monopoly microstrip antenna for RFID applications. The microstrip monopole antenna has been chosen for its advantages over conventional antennas. Conventional antennas are large and not suitable for RFID applications. The use of a microstrip patch antenna provides several advantages, with a compact shape and good radiation manners. On the other hand, microstrip monopole antennas have the additional advantages of compatibility with reduced size, weight, assembly compatibility, microwave and millimetre wave integrated circuits, and microwave monolithic integrated circuits (MMICS).

The main functional drawbacks of microstrip monopole antennas are the very narrow frequency bandwidth, which is usually only a fraction of a percentage or a maximum of a few percent. In addition, loss of dielectric and conduction at thin spots may be significant, resulting in insufficient antennas. However, microstrip antennas are easy to construct and support linear and circular polarizations.

1.3 Objectives

The objectives of this project are:

i. To design and develop a microstrip patch antenna operating frequency at 2.4 GHz for the RFID application.
ii. To develop and analyse the antenna performance using modified ground
iii. To verify the simulation results with measurement results.

1.4 Scope of Study

The scope of this project is follows:

i. A microstrip monopole antenna designed and simulated using Computer Simulation Technology (CST) Microwave. The microstrip monopole antenna at 2.4 GHz for RFID applications. The antenna was fabricated using FR4 substrate material.
ii. Modified ground is applied to improve the antenna performance.
iii. The antenna was simulated with the computer simulation technology microwave studio. This software was chosen because it is a specialized Tool for 3D simulation of high frequency components.
iv. To fabricate antenna using circuit technology and validate the simulated result with measured results.
v. The microstrip monopole antenna will be tested by using Network Analyser.

1.5 Thesis outline

The thesis outline, it will be covered in its entirety. This report is divided into sections. Each section will cover the topics needed.

As far as Chapter 1 is concerned, it covers the introduction of the project. Few explanations will be made due to the project. It also includes objectives, scope and thesis outline.

Chapter 2 is a chapter that provides a literature review of the project. This chapter focuses on specific topics. The literature review starts with the introducing the antenna calculations, formulations, line of the transmission and antenna trends.

Chapter 3 deals with the methodology, focusing on the method with which the project was accomplished. The methodology is shown in the organization chart. Moreover, it is detailed in the form of sentences. The expected result and the analysis are discussed in Chapter 4.

This chapter will provide details on the expected results for the entire project, as well as the frequency response to be achieved at the end of the simulation process. In addition, it also provides a detail on the analysis of the result due to the fabrication and fluidity of the tests. The discussion focus on the formulations, calculation, fabrication and testing

The last chapter is Chapter 5, which is a general conclusion for the project. There are also works in the future. The conclusion refers to the plan. It is important to ensure that our goal is achieved.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter describes some similar earlier work, pertinent journals and research that include the design of microstrip monopole antennas that can provide an idea for the implementation of this project. This chapter also covers the background of the RFID application, the RFID key, the microstrip monopole structure of the smaller antenna, and the antenna parameters as well.

2.2 Background of RFID

Radio Frequency Identification (RFID) is an Automatic Data Acquisition System (AIDC) that has the potential to have a major impact on the economies of many industries [11]. Although Radio Frequency Identification (RFID) is a comparatively old technology and uses Radio Frequency signal for communications, the latest advances in technology have made RFID suitable for new consumer applications and configurations. These developments tend to transform, human resources, logistics, and other areas. As a result of research and development, technological advances and human development stimulate the need to store and process information in real time and the use of radio frequency identification in various areas have expanded.

RFID also enables staffs to achieve organizational goals throughout production while managing data via RFID technology. RFID technology makes it easy to track a wide range of objects, including people, goods, vehicles and assets. The explosive growth of the population and the introduction of large data have placed RFID technology at the top of each domain. RFID systems are an automatic detection system such as an optical barcode. Barcode can persist the best solution, especially in the average term. RFID is not as low-cost as traditional labelling techniques, but adds value and is currently at an important price level where consumer products can spread widely. Currently, the biggest drop is the cost of personal RFID tags and the cost of installation of the system [12]. Table 2.1 makes a contrast of the features for bar codes and RFID.

Table 2.1: Evaluation of Bar-code vs. RFID

Attribute	Bar-code	RFID
Positive	➢ inexpensive ➢ broadband consumption ➢ readable for human	➢ No need line-of-sight ➢ Huge memory data transfers along with products ➢ Read dynamic data
Negative	➢ Line-of-sight needs for data transferring ➢ data storage is limited ➢ Environmentally sensitive	➢ expensive ➢ Reads easily the product ➢ Adoption is limited

The foundations of RFID technology date back to World War II. The Germans, Japanese, Americans and British all were warned on the approaching plane when they were away in 1935 using radar discovered by Scottish physicist Sir Robert Alexander Watson Watts. However, it was impossible to distinguish the enemy planes from country’s own ones. The Germans found that when the aircraft was transferred, when it returned to the base, the reflected radio signal would change, warning the radar personnel on the ground. The Germans used this simple method to identify their aircraft. The British developed the first active friend or enemy identification system (IFF) by simply installing a transmitter on each British aircraft that received signals from the aircraft. This makes the aircraft very friendly [13].

In the past few decades, RFID technology has gone through many stages. This technology has been used to track delivery of goods, courier services and baggage handling. Other applications include automatic toll payment, departmental access control for large buildings, personal and vehicle control in specific areas, safety of items that should not dispensation the space, tools tracking by engineering companies, clinic file systems, etc [14].Table 2.2 shows RFID development finished the past few decades.

Table 2.2: RFID development completed the previous decades [11].

Period	**development**
1940 - 50	Radio frequency identification technology was used for the period of the Second World War.
1950 - 60	Introduction to radio frequency identification technology, research laboratory testing.
1960 - 70	The improvement of the RFID system begins, the field tests initiate, the first Sensory and Control Point of RFID was established, the first EAS was out to prevent robbery.
1970 - 80	The rapid growth of RFID development, the acceleration of RFID testing, the implementation of initial implementation of RFID, the release of RCA and Fairchild, the "Electronic ID System", the electronic charging test of the Port Authority of New York and New Jersey
1980 -90	Saleable tenders for RFID are widely distributed. Tenders occur in the areas of transport, industry, access to people and animal identification. Toll roads are equipped with RFID worldwide
1990-2000	RFID is becoming part of everyday life, and with the advent of the first open RFID standards commonly used for toll collection, animal identification and personal identification, MIT finds the car identity.

2.3 RFID tag

RFID tags include microprocessors, transmitters, and antennas that can read and write data in text without contact between readers and tags. There are two broad classifications of RFID system and they are: passive tags and active tags. Active tags have power requirements, long-distance readings, and are commonly more costly than passive tags; they do not have, meaning they will not be used for affordable products. There are also semi passive RFID tags and runs for special tenders. Semi-passive tags use a battery to control the chip, but exchange data with the reader through the sector. Active and half-pass tags continue to broadcast their own signals, often used to accurately track assets in high-speed environments, such as payments or real-time. Passive tags are cheaper, do not need batteries or repairs, are powered by the magnetic field of the reader, and have a little read time. The tags also has an unlimited durability and is small to fit a practical adhesive tags. The use of passive RFID systems is economical for many industries due to the lowest price. Passive RFID tags include applications such as file monitoring, smart tags, chain supply management and access control system [15-19]. RFID tags can be classified into various categories shown in Table 2.3 there are two fundamentally different RFID design methods to transmit reader power to tags. Field system using transponder tag and repelling power induction (magnetic) coupling circulating around antenna and reader system. A long field related to the true power of free space spreading electromagnetic waves [20].

Both can continue running by sending enough power to the remote control. Usually 10μW to 1 mW, be contingent on the type of tag. Near-field coupling methods are typically practical to RFID systems in which operates in the low frequency and high frequency bands at comparatively low spaces, while for very high frequencies; the mass field coupling is higher (UHF) and microwave RFID systems. The length of the tag depends on the electromagnetic field generation system and closest resonance frequency or wavelength. Often one is called the Radian pattern. Since modifications in electromagnetic fields take place slowly, the limit does not precisely defined; the main magnetic field begins from the antenna and induces the electric field lines inside the room (near-field) [21-23]. The choice of technology for a specific application results from a thorough examination of the various characteristics, costs and performance characteristics of different RFID technologies according to the needs of the program. RFID systems can only store small amounts of data on the tags (usually less than 2 kbit data = less than 250 characters or less than 8 characters). As a result, the design of the information stored on the label is an important element of the application [24].

Table 2.3: Categorization of RFID tags

Used by design and technology	
Passive	➢ also called "pure passive", "reflector" or "beam-fed" ➢ Getting the power from the reader ➢ The reader sends electromagnetic waves that cause current to the tag's antenna, which reflects the transmitted RF signal and adds information by adjusting the reflected signal
Semi-passive	➢ Uses a battery to keep the memory on the tag or to power the electronic components allowing the tag to form the reflected signal ➢ It communicates in the same way as other passive tags.
Active	➢ It works with an internal battery that controls the microchip circuit and sends a signal to the reader ➢ mostly offers a wider range of active tag readings more
By the tag's memory type	
Class 0	Pre-programmed passive tag, Read Only.
Class 1	Read Many (WORM) passive tag, Write Once.
Class 2	Passive Read / Write tags that can be written in the supply chain at any time
Class 3	Read-write with built-in sensors that can record parameters such as temperature, pressure and motion.

2.4 RFID Reader

The reader for RFID, sometimes referred to as interrogator is a collection of data collection that is responsible for powering and transmitting tags with signals, utilization and the computer network. Readers are equipped with an antenna to send and receive signals, transceivers, and code / data interrupt processors. In passive systems, RFID readers emit the energy field that produces tags and raises their chips, and allows them to send or store data. The active tags send signals periodically, so that the data can be collected by a plurality of scattered readers [25].

Readers may possibly moveable terminals or fixed devices placed at calculated points, similar to stock entrances, gathering lines, or toll booths (door readers). Readers can use PCMCIA cards (International Computer Memory Card Persons Association) to attach laptops that are usually power-driven by their own power (battery) or vehicle. Readers usually operate on radio frequencies, so if tags from three different manufacturers use three different frequencies, the seller may have several readers in some places, which adds to the cost.

Table 2.4: Types of RFID readers

By design and technology used	
Read	➢ only reads data from the tag ➢ Usually a micro-controller unit with wound output coil, sensor top, comparative designed to send energy tags and reading data there from by sensing rear scattering.
Read/ write	➢ reads and writes data from/on the tag
By fixation of the device	
Stationary	➢ The device is attached in a fixed way, for example at the entrance gate, respectively at the exit gate of products
Mobile	➢ The reader is a handy, movable device.

2.5 Frequency range of RFID

The range of the RFID tag varies with frequency. Most RFID systems operate under Industrial Science (ISM). It is available free of charge in low power and low power systems [27]. The team defined the International Telecommunication Union (ITU). Different power and bandwidth rules are subjected to operating devices on each. Table 2.5 lists the operating frequencies and RFID performance characteristics. This frequency decided that we do not lack, to oppose, would be a compliment, that the problems of not bothering to keep. The RFID tag was chosen to be placed in the application. RFID tags are different at different frequencies. EPG is the most important global ISO group working on the development of international standards in the UHF RFID band [28]. To avoid the use of different radio frequencies, most of the world's communities want to meet standard ITUs. Four frequency bands used in the design of the tags:

i. Low frequency (125-135 KHz)
ii. High frequency (13.56 MHz)
iii. Ultra-high frequency(860-960 MHz)
iv. Microwave (2.45 and 5.8 GHz)

Tags have Different frequencies and different functions. They are different when they are characterized by different types of materials. The reading interval varies from a few centimetres to several meters. Due to government regulations and customer orders, multiple frequencies selected can be selected.

I. Low frequency tags (125-135 KHz)

The LF tag requires helical antenna or a Spiral Antenna with a few hundred core revolutions. They are expensive to produce. Water suppression is lower than for high frequency tags. These tags are used for the first time and are always used to track animals. LF Do not rotates or moves the metal. The LF Bridge is suitable for applications that need to read a small amount of data at low speed and minimum distance.

II. High frequency (13.56 MHz)

The HF has a simple antenna design with a low spool (5 to 7 turn) and is as a result thinner and cheaper to fabrication than lower frequency. Low Frequency is not pretentious by water due to high frequency. High-frequency are very useful for tenders needing a small reading distance or where the identified items enclose water comparable pharmaceuticals, humans, and animals., referred to as medications, humans and animals. LF and HF readers have lower data like LF and UHF readers. HF has been used in European and the classic read range of HF tags is about 30-70 cm. HF reading antennas fill the volume around antenna and should be Omni-directional.

III. Ultra-high frequency (860-960 MHz)

The Ultra-high frequency tag requires very good communication without line-of-sight (except "lossy" materials). They always have a higher data rate and a normal reading range of up to 5 m. The adjustable UHF antenna reader provides an adjustable reading zone. This is the frequency range most frequently discussed in supply chain management applications. Ultra-high frequency does not enter water / tissue, Ultra-high frequency readers are more costly than HF, and technology is not more mature than HF. In addition, regulations on the use of UHF vary in dissimilar parts of the world. Different countries allow different frequencies, number of channels, maximum power and duty cycle.

IV. Microwave Frequency (2.45, 5.8 GHz)

Microwaves also have a good visibility communication (with the exception of "lossy" materials). It gives you more data rates and distance reading up to 15 meters. This tag is also effective for metals with tuning / design adjustment. The microwave reader antenna is directed to ensure controlled reading area. Table 2.5 below summarizes the RFID frequencies and related applications.

REFERENCES

1. Dhengale, B. B., &Karia, D. C. (2015, January). A 5.8 GHz ISM band Microstrip antenna for RFID applications. In Nascent Technologies in the Engineering Field (ICNTE), 2015 International Conference on (pp. 1-4). IEEE.
2. Hira, A., Sarker, N., &Goni, M. O. (2014, December). Design and development of a patch antenna for ISM band passive RFID tag. In Electrical and Computer Engineering (ICECE), 2014 International Conference on (pp. 188-191). IEEE.
3. Liu, Q., Shen, J., Yin, J., Liu, H., & Liu, Y. (2015). Compact 0.92/2.45-GH dual-band directional circularly polarized microstrip antenna for handheld RFID reader applications. IEEE Transactions on Antennas and Propagation, 63(9), 3849-3856.
4. Singh, A. K., Das, T. K., & Behera, S. K. (2017, March). Design of RFID reader antenna for healthcare applications. In Wireless Communications, Signal Processing and Networking (WiSPNET), 2017 International Conference on (pp. 2527-2530). IEEE.
5. Nornikman, H., Malek, F., Saudin, N., Zainuddin, N. A., Shukor, M. M., Aziz, M. A., ... & Othman, M. A. (2013, November). Dual layer rectangular microstrip patch antenna with H-slot for 2.4 GHz range applications. In Instrumentation, Communications, Information Technology, and Biomedical Engineering (ICICI-BME), 2013 3rd International Conference on (pp. 44-48). IEEE.
6. B. H. Ahmad, M. M. Ariffin, H. Nornikman, N. M. S. Roslan, M. Z. A. Abd Aziz, M. A. Atiqa, A. R Ayuni, Y. M. Ming, Y. P. Yin, "Parametric Study on the Compact G-shape Monopole Antenna for 2.4 GHz and 5.2 GHz Application", International Journal of Engineering and Technology (IJET), vol. 5, no. 1, pp. 512-518, 2013

7. G. Liu, L. Xu, Z. Wu, "Miniaturized Circularly Polarized Microstrip RFID Antenna Using Fractal Metamaterial," International Journal of Antennas and Propagation, vol. 2013, article ID 781357, pp. 1-4, 2013

8. Kaswiati, W. S., &Suryana, J. (2012, October). Design and realization of planar bow-tie dipole array antenna with dual-polarization at 2.4 GHz frequency for Wi-Fi access point application. In Telecommunication Systems, Services, and Applications (TSSA), 2012 7th International Conference on (pp. 218-222). IEEE.

9. Caso, R., Michel, A., Rodriguez-Pino, M., &Nepa, P. (2014). Dual-band UHF-RFID/WLAN circularly polarized antenna for portable RFID readers. IEEE Transactions on Antennas and Propagation, 62(5), 2822-2826.

10. Hsu, H. T., & Huang, T. J. (2014). A Dual-Band Antenna Array for Radio-Frequency Identification (RFID) Handheld Reader Applications. IEEE Transactions on Antennas and Propagation, 62(10), 5260-5267.

11. Kanngieser, A. (2013). Tracking and tracing: Geographies of logistical governance and labouring bodies. Environment and Planning D: Society and Space, 31(4), 594-610.

12. Lodgher, A., Perkins, J. A., Yang, Y., Jones, E., & Hawkins Jr, H. G. (2010). Feasibility and applications of RFID technologies to support right-of-way functions: Technical report. Texas Transp. Inst., The Texas A&M Univ. Syst., College Station, TX, USA, Tech. Rep. 0-6142-1.

13. Yang, A., & Hancke, G. P. (2017). RFID and Contactless Technology. In Smart Cards, Tokens, Security and Applications (pp. 351-385). Springer, Cham.

14. Ahsan, K., Shah, H., & Kingston, P. (2010). RFID applications: An introductory and exploratory study. arXiv preprint arXiv:1002.1179.

15. Flores, J. L. M., Srikant, S. S., Sareen, B., &Vagga, A. (2005, January). Performance of RFID tags in near and far field. In Personal Wireless Communications, 2005. ICPWC 2005. 2005 IEEE International Conference on (353-357). IEEE.

16. Arpitha, B. N., & Padma, M. C. (2015). An IOT Project Integrated with RFID and GPRS.

17. Sui, J., & Wu, K. L. (2017). A general T-stub circuit for decoupling of two dual-band antennas. IEEE Transactions on Microwave Theory and

Techniques, 65(6), 2111-2121.

18. Zhao, L., & Wu, K. L. (2015). A dual-band coupled resonator decoupling network for two coupled antennas. IEEE Transactions on Antennas and Propagation, 63(7), 2843-2850.

19. Mtita, C., Laurent, M., &Delort, J. (2016). Efficient serverless radio-frequency identification mutual authentication and secure tag search protocols with untrusted readers. IET Information Security, 10(5), 262-271.

20. Ahmad Mabrook Ali Saad, "Chapter 3, Dual-Band Microstrip Loop Antenna for Wireless Application", (Unpublished), 2013.

21. Bisht, S., Saini, S., Prakash, V., &Nautiyal, B. (2014). Study The Various Feeding Techniques of Microstrip Antenna Using Design and Simulation Using CST Microwave Studio. International Journal of Emerging Technology and Advanced Engineering, 4(9).

22. Rao, U. S., &Siddaiah, P. (2018). Design, Simulation and Performance Comparison of 1, 2, 4 and 8 Elements Quarter-Wave Transformer-Fed Circular Patch Antenna Array at L Band for Airborne Applications. In Innovations in Electronics and Communication Engineering (pp. 495-516). Springer, Singapore.

23. Abdulhasan, R. A. (2015). Design of microstrip ultra wide band antenna with two notch filters for wireless communication (Doctoral dissertation, Universiti Tun Hussein Onn Malaysia).

24. Ali, N. T., Mubarak, K., McEwan, N., Mezher, K. A., Kulaib, A., & Al-Zarouni, A. (2010, December). Reflectometer Apparatus for rapid determination of water-cement ratio. In Electronics, Circuits, and Systems (ICECS), 2010 17th IEEE International Conference on (pp. 1061-1063). IEEE.

25. Rao, U. S., &Siddaiah, P. (2018). Design, Simulation and Performance Comparison of 1, 2, 4 and 8 Elements Quarter-Wave Transformer-Fed Circular Patch Antenna Array at L Band for Airborne Applications. In Innovations in Electronics and Communication Engineering (pp. 495-516). Springer, Singapore.

26. Barreto, E. L., d'Assunção, A. G., &Mendonça, L. M. (2015, March). A new fractal antenna array for wireless communications. In Applied Computational Electromagnetics (ACES), 2015 31st International Review

of Progress in (pp. 1-2). IEEE.

27. Athari, K., Ghobadi, C., Layegh, M. A., &Nourinia, J. (2014, September). Design of a novel CPW-fed monopole antenna using elliptical slots for WLAN and mobile WiMAX applications. In 7'th International Symposium on Telecommunications (IST'2014).

28. Basha, T. G., Krishna, K. T., Chandrakala, C., Kishore, V., &Aruna, D. A New Omni-directional Monopole Antenna for Interference Reduction. Editorial Board, 637.

29. Marotkar, D. S., Zade, P. L., &Kapur, V. (2014). Study of Microstrip patch antenna using EBG for wireless communication.

30. Tubbal, F. E. M., Raad, R., & Chin, K. W. (2015). A survey and study of planar antennas for pico-satellites.

31. Cipullo, G. M., Araujo, H. X., Casella, I. R., &Capovilla, C. E. (2014). Text Antenna based on Meander Line for RFID Integrated Circuit Transponders.Journal of Communication and Information Systems, 28(1).

32. Jain, S. K., &Shrivas, G. (2015, February). Miniaturization of microstrip antennas using defected ground plane. In Recent Advances in Electronics & Computer Engineering (RAECE), 2015 National Conference on (pp. 149-153). IEEE.

33. Kamalvand, P., Pandey, G. K., &Meshram, M. K. (2016). RFID tag antenna for ultra and super high frequency band applications. International Journal of RF and Microwave Computer-Aided Engineering, 26(7), 640-650.

34. Qing, X., C. K. Goh, and Z. N. Chen, "Impedance characterization of RFID tag antennas and application in tag co-design," IEEE Transactions on Microwave Theory.

35. Caso, R., Michel, A., Rodriguez-Pino, M., &Nepa, P. (2014). Dual-band UHF-RFID/WLAN circularly polarized antenna for portable RFID readers. IEEE Transactions on Antennas and Propagation, 62(5), 2822-2826.

36. Madhav, B. T. P., Pisipati, V., Bhavani, K. V. L., & Sreekanth, P. rectangular microstrip patch antenna on liquid crystal polymer substrate.

37. Yan, D., Xiang, N. X., Wang, P., & Cheng, Y. (2017, October). A dual-band planar monopole antenna for WLAN/Wi-Fi applications. In Chinese Automation Congress (CAC), 2017(pp.6345-6348).IEEE.